LANDFILL GAS UTILIZATION FEASIBILITY STUDY
ROCKY FACE LANDFILL
DALTON, GEORGIA

Prepared for:

Dalton-Whitfield Regional Solid Waste Management Authority
P.O. Box 1205
Dalton, Georgia 30722-1205
(706) 277-2545

Prepared on behalf of:

United States Environmental Protection Agency
Landfill Methane Outreach Program
Washington, D.C. 20460

Prepared by:

EMCON
13111 N.W. Freeway, Suite 600
Houston, Texas 77040
(713) 996-4581

And

Eastern Research Group
PO Box 2010, 1600 Perimeter Park
Morrisville, NC 27560
(919) 468-7800

January 9, 2002

DISCLAIMER

This feasibility assessment was prepared specifically for the DWRSWMA on behalf of the U.S. EPA Landfill Methane Outreach Program. Projections and findings are based on engineering judgment. The EPA and its contractors, EMCON and ERG, do not guarantee the quantity of available landfill gas or the financial feasibility, and no other warranty is expressed or implied. No other party is intended as a beneficiary of this work product, its content, or information embedded therein. Third parties use this report at their own risk. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLES

Table **Page**

FIGURES

SECTION 1

INTRODUCTION

OBJECTIVES

The EMCON/ERG Project Team (EMCON/ERG), on behalf of the U.S. Environmental Protection Agency's (EPA's) Landfill Methane Outreach Program (LMOP), has assessed the feasibility of using of landfill gas (LFG) from the Dalton-Whitfield Regional Solid Waste Management Authority (DWRSWMA). The purpose of this report is to evaluate the LFG generation and recovery potential at the Rocky Face Landfill and provide a preliminary evaluation of the approximate cost of recovering the energy present in the gas.

INTRODUCTION

Landfills produce LFG as organic materials decompose under anaerobic conditions. LFG is composed of approximately equal parts of methane (CH_4) and carbon dioxide (CO_2) with trace concentrations of other gases, including non-methane organic compounds (NMOCs). Landfill gas can be an asset when it is used as a source of energy. It is classified as a medium-Btu gas with a heating value of 350 to 500 Btu/scf, approximately one-half that of natural gas.

LFG can often be used in place of conventional fossil fuels in certain applications. Landfill gas is inherently a low-pollution fuel with respect to nitrogen oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC), and volatile organic emissions. The flame temperature that results from the burning of LFG is generally low, so NOx emissions are generally about 70% lower than those of natural gas combustion. The flame temperature, however, is not so low as to aggravate HC or CO emissions. Emissions from LFG combustion can be as low as 22 ppm of NOx, 5 ppm of CO, and 5 ppm of HCs. By using LFG to produce energy, landfills can significantly reduce their emissions of methane, a potent greenhouse gas. Use of LFG also avoids the need to generate energy from fossil fuels, reducing emissions of carbon dioxide (CO_2) and sulfur dioxide (SO_2) from fossil fuel combustion.

LANDFILL BACKGROUND

The Rocky Face Landfill (Westside, Phases 1 and 2), first opened in 1972 and accepted its last shipment of waste on March 30, 1999 (formal closure is still pending at time of writing). It is located in a predominantly rural area of Dalton, Georgia, though a few trailer homes are located in close proximity to it. The Dalton-Whitfield Regional Solid Waste Management Authority (DWRSWMA) operates the landfill, which spreads across 45 acres and is estimated to contain between 700,000 and 1,000,000 tons of municipal solid waste. On average, the landfill is 28-30 feet deep with waste. The Rocky Face Landfill does not have a flexible membrane liner (FML) and thus has no means of collecting leachate.

To ensure compliance with Subtitle-D regulations pertaining to LFG migration, 46 passive vents were installed in October 2000. This is the only LFG system that is currently in place at the landfill.

At present, the landfill would *not* be eligible for Section 29 federal tax credits if it began generating usable energy from LFG. Due to its relatively small size, it is also *not* subject to the provisions of the New Source Performance Standards/Emissions Guidelines (NSPS/EG).

SECTION 2

LANDFILL GAS GENERATION AND RECOVERY

To estimate the potential LFG recovery rate for the landfill, EMCON/ERG used EPA's E-Plus software, which employs a first-order decay equation identical to the algorithm in the widely used EPA Landfill Gas Emissions Model (LandGEM). For comparison purposes, EMCON also used its proprietary LFG Estimation model to provide additional insight into the LFG generation and recovery potential of the site. The EMCON LFG Estimation model also has some additional features that can make it a useful tool to use for comparison purposes.

E-PLUS MODEL DESCRIPTION

The LFG generation model requires a few basic inputs such as the LFs dates of operation and the amount of waste currently in place in the landfill. The model employs a first-order exponential decay function. This function is based on the idea that the amount of LFG generated from solid waste reaches a peak after a certain time lag for methane generation. The model assumes a one-year time lag between placement of waste and LFG generation. The model also assumes that for each unit of waste, LFG generation decreases exponentially (after the one-year time lag) as the organic fraction of the waste is consumed.

For sites with known (or estimated) year-to-year solid waste acceptance rates, the model estimates the LFG generation rate for a given year using the following equation, which is published in Title 40 of the U.S. Code of Federal Regulations (CFR) Part 60, Subpart WWW.

$$Q_M = \sum_{i=1}^{n} 2\, k\, L_o\, M_i \left(e^{-kt_i}\right)$$

Where: $\sum_{i=1}^{n}$ = sum from opening year+1 (i=1) through year of projection (n);

Q_M = maximum expected LFG generation flow rate (m^3/yr);
k = methane generation rate constant (1/yr);
L_o = methane generation potential (m^3/Mg);
M_i = mass of solid waste disposed in the i^{th} year (Mg);
t_i = age of the waste disposed in the i^{th} year (years).

The above equation is used to estimate LFG generation for a given year from all waste disposed up through that year. One may develop multi-year projections by varying the projection year and re-applying the equations. The point of maximum LFG generation normally occurs in the closure year or the year following closure (depending on the disposal rate in the final years).

EMCON MODEL DESCRIPTION

The EMCON model shares the same origins as the E-Plus model. EMCON, however, has added variables and made modifications based on its experience with landfill gas recovery. The EMCON model incorporates information about the landfill's waste stream, the LFG generation potential of the individual waste stream components, as well as the moisture, temperature, and associated climatic factors of the disposal area. The EMCON model's output is shown in Appendix B.

ESTIMATED LFG RECOVERY

As part of the estimation of the amount of LFG that one could expect to actually *recover* from the site, an approximate recovery efficiency rate was applied to the LFG generation rates provided by the models. The landfill does not have an FML liner and the final cap configuration was installed in accordance with Subtitle D regulations. Based on these conditions, a 75% collection efficiency was estimated.

MODEL INPUTS

Table 2-1 shows the information about past and expected future waste quantities that was provided by DWRSWMA. These waste quantities were used to develop the LFG recovery estimates in both models.

TABLE 2-1. ANNUAL WASTE QUANTITIES

Year	Tons Waste	Year	Tons Waste
1972	30,000	1986	30,000
1973	30,000	1987	30,000
1974	30,000	1988	30,000
1975	30,000	1989	30,600
1976	30,000	1990	27,640
1977	30,000	1991	20,921
1978	30,000	1992	24,520
1979	30,000	1993	21,530
1980	30,000	1994	23,789
1981	30,000	1995	24,330
1982	30,000	1996	24,188
1983	30,000	1997	37,166
1984	30,000	1998	26,675
1985	30,000	1999	1,474

These acceptance rates add up to 772,833 tons of waste in place over the lifetime of the landfill. This is at the low end of the earlier-cited estimate of 700,000 to 1,000,000 tons of waste in place provided by DWRSWMA. A degree of uncertainty about the amount of waste in place (and thus about the amount of LFG that will be generated) is implied by the disparities between these estimates. The models' predictions, to the extent that they are affected by this uncertainty, would likely err on the side of predicting *too little* LFG production.

MODEL RESULTS

Based on the inputs shown above, the models produced the estimated LFG recovery flow rates shown in Table 2-2 and graphically presented in Figures 2-1 and 2-2. (Note that the table and figures show potential gas recovery rates rather than gas generation rates. The recovery rate is assumed to be 75% of the predicted gas generation rate.)

TABLE 2-2. LFG RECOVERY ESTIMATES

Year	Accumulated Tons of Waste	LFG Recovery Potential based on E-Plus Model (scfm)	LFG Recovery Potential based on EMCON Model (scfm)
1999	772,833	203	155-232
2000	772,833	195	153-230
2001	772,833	187	152-228
2002	772,833	180	150-224
2003	772,833	173	145-217
2004	772,833	167	137-205
2005	772,833	160	127-190
2006	772,833	154	116-174
2007	772,833	147	106-159
2008	772,833	142	97-146
2009	772,833	136	90-135
2010	772,833	131	83-124
2011	772,833	126	76-114

Note: These projections have been prepared specifically for the DWRSWMA on behalf of the U.S. EPA Landfill Methane Outreach Program, and are based on engineering judgment and represent the standard of care that would be exercised by a reasonable professional experienced in the field of landfill gas projections. EMCON/ERG does not guarantee the quantity of available landfill gas, and no other warranty is expressed or implied. No other party is intended as a beneficiary of this work product, its content, or information embedded therein. Third parties use this report at their own risk. EMCON/ERG assumes no responsibility for the accuracy of information obtained from, compiled, or provided by other parties.

Figure 2-1 LFG Generation and Recovery Projection Rocky Face Landfill based on E-Plus Model

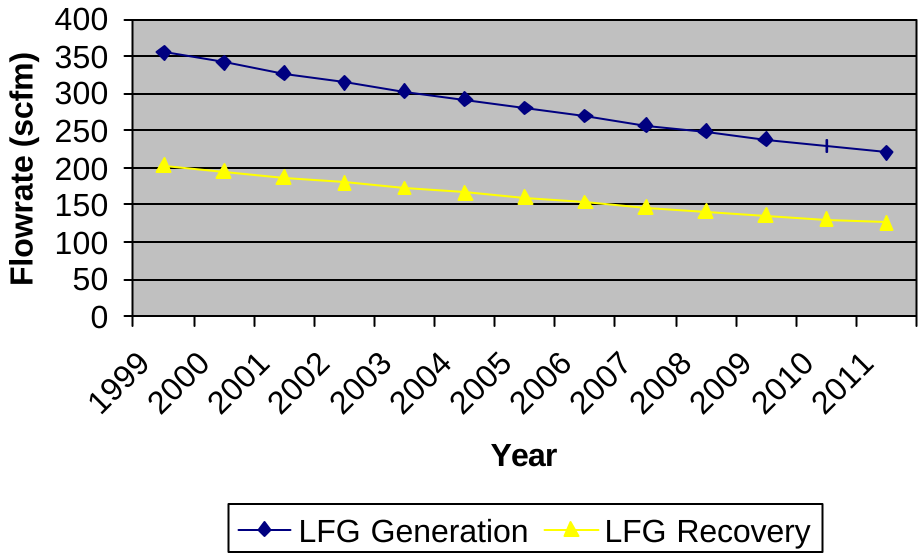
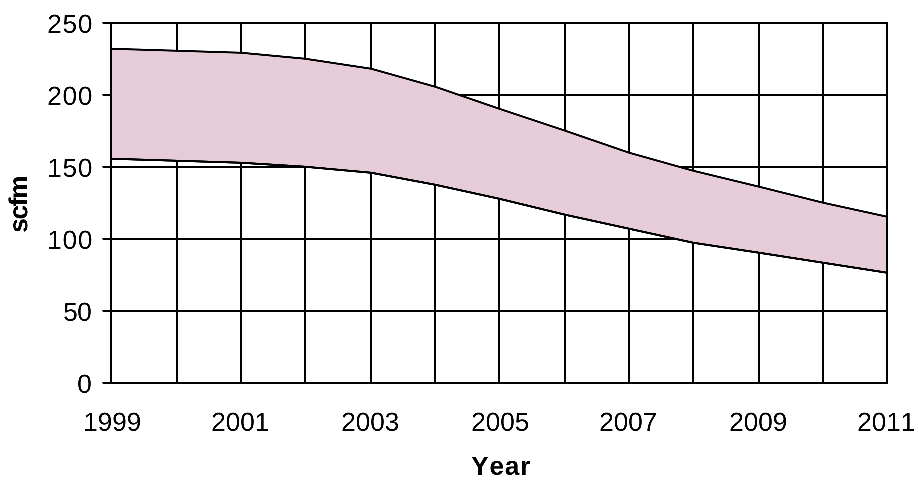


Figure 2-2. Gas Recovery Rate Rocky Face Landfill based on EMCON Model



Generally, most LFGTE projects are assessed for a timeframe of 10-20 years, with 15 years being fairly typical. Since this project is on the downward leg of the LFG generation cycle and only small quantities of LFG are expected at present or in the future, we will take the conservative approach of assessing the project using a 10-year life cycle.

The results from the two models are very similar; the E-Plus model results are within the EMCON range for all of the years modeled except the last 3 years. In general the EMCON model predicts a lower gas flow at its lower bound and it predicts a quicker reduction of gas flow over the years. As shown in the table and figures, the models predict that the highest gas recovery rate (perhaps between 155 and 232 scfm) occurs in 1999. Recovery rates decline each year, such that by 2011, the recovery rate may be from 76 to 126 scfm.

GAS GENERATION CONCLUSIONS

Over the next 10 years the E-Plus Model predicts a minimum LFG recovery rate of approximately 126 scfm in the year 2011, while the EMCON LFG estimation model predicts a recovery rate of 76 to 114 scfm in the year 2011. Based on the low pressures tested at the site, it would be prudent to focus more on the lower estimates over the 10-year period than on the higher estimates.

SECTION 3

END USE AND ECONOMIC EVALUATION

This section presents information about three potential end uses for the LFG collected from the Rocky Face Landfill and their economic viability:

1) Heating an on-site greenhouse;
2) Running microturbines to generate electricity;
3) Running a small IC engine to generate electricity.

Economic evaluations for each option have been completed, taking into account capital costs for equipment and installation, annual operational costs, and the installation of conveyance piping necessary to extract the LFG from the existing passive vents. Where applicable, the economic analyses were conducted using the E-Plus software. For the purpose of comparison and to provide data about technologies for which no mechanism currently exists within the E-Plus model, economic evaluations using EMCON's internal economic analysis software were performed. Appendices C and D contain the detailed results of these analyses.

GAS RECOVERY

Since the landfill is currently under no regulatory obligation to install an active gas collection system, the LFG gas collection system is included in the economic evaluation of each option. Additionally, it is assumed that the well field gas blowers and standby flare system would be located near any greenhouse, microturbines or IC engine, thereby eliminating the need for any additional blowers to pump gas to the equipment. The following assumptions were made in order to estimate the LFG supply costs:

- The E-Plus model's estimate for the gas collection system is $246,000, including flare and blowers. Gas well drilling is not included since the wells are already in place.

- The LFG pipeline would be below ground and constructed of 6-inch diameter HDPE pipe and would be extended 1,000 feet to the combined blower, flare and equipment location. The cost of these pipes and valves is estimated at $25,000.

- Annual gas collection system operation and maintenance costs of $29,000 per year are included in the annual cost in the evaluations of each option.

For all three options, LFG must be collected and treated before it can be used. Moisture and particulates typically are removed through a series of filters, knockout vessels, and/or driers. Following this minimal level of gas cleaning, gas quality of 35 to 50 percent methane is typically available. This level of methane concentration is generally acceptable for use in a variety of equipment, including boilers and engines. Although most pieces of equipment are designed to handle natural gas that is nearly 100 percent methane, they can be modified to handle gas with lower methane content.

GREENHOUSE HEATING

Future Farms (a division of American Hydroculture, Inc.) has expressed an interest in using the landfill gas from the Rocky Face Landfill to produce 2 MW of electricity to heat, cool and humidify a greenhouse to be placed near the landfill. The landfill gas can be used to supplement natural gas usage to heat a greenhouse, however, the landfill is not projected to produce enough gas to generate the desired 2 MW of energy. The gas from this landfill is projected to be enough to produce 200-420 kW of energy.

Based on the available data, using the landfill gas in a boiler to heat a small greenhouse could be the most viable option for the Rocky Face Landfill. Of all the options, it has the lowest requirements for LFG flow. Outlined below are some of the primary considerations for estimating the energy requirements of a greenhouse. Using the gas to produce electricity to be used in a greenhouse is an option. The viability of using landfill gas to produce electricity is discussed in the next subsection, "Electricity Generation."

Greenhouse Energy Requirements

While electricity is commonly used to power fans, lights, and other miscellaneous equipment, fuels such as oil, natural gas, and propane are typically burned in a boiler to heat a greenhouse. A greenhouse's fuel needs depend on a number of factors:

- Crop type dictates the temperature that must be maintained. For example, carnations can tolerate temperatures in the low 50s, whereas roses require warmer temperatures.

- Geographic location influences the amount of energy necessary to maintain the optimal growing temperature for a crop. At colder, northern latitudes, it takes between 100,000 and 200,000 Btu per square foot (ft^2) of floor area per year to heat a greenhouse during the growing season. A University of California report (Reducing Energy Costs in California Greenhouses, Leaflet 21411) states that greenhouses use an average of 115,000 Btu/ft^2 of floor area per year. Considering that the Rocky Face Landfill is in Georgia, a heating requirement on the lower end of this range is expected.

- The kind of building materials used to construct the greenhouse, from glazing materials to ventilation systems, affect energy demand. Glass, rigid plastic, or plastic film used for walls and ceilings each have different thermal efficiencies which allow different amounts of heat loss.

Outlined below are estimates of the economics involved with using the LFG to heat a future greenhouse. These costs include collecting the gas and conveying it to the greenhouse. The cost assumptions for the collection system (listed earlier) are the only costs associated with getting the gas to the greenhouse. Also listed below (for informational purposes) are estimates of an appropriate greenhouse size and the costs for greenhouse construction. Note that the costs of greenhouse construction are typically incurred by the company that plans to build and operate the greenhouse business, not by the landfill.

Preliminary Greenhouse Sizing

Based on the E-Plus and EMCON models, the landfill is expected to be able to recover between 152 and 228 scfm of LFG in 2001, decreasing to a range of 76 to 126 scfm by 2011. From this information, it is determined that a small greenhouse project could be supported by this landfill. A common greenhouse design and construction approach is to provide greenhouses that are constructed of multiple units of the same size. This provides some flexibility to the landfill owner. For this study we have assumed the greenhouse size would be ten units of 22' x 96' (representing 21,120 ft^2 of floor space and 44,720 ft^2 of surface area). The greenhouse requires an LFG flow rate of approximately 70 to 120 scfm at 50% methane. Based on model estimates, this size of greenhouse should be supportable for about 10-15 years from the present. However, because of the uncertainty in landfill gas flow, it is suggested that further flow analyses be conducted once the collection system is completed. At that time it may be determined that a smaller or larger greenhouse is needed.

Preliminary Greenhouse Construction Costs

The EMCON/ERG team has gathered additional information from Jaderloon Company, Inc. (an LMOP partner and a greenhouse designer) on greenhouse heating requirements, sizes, and costs. Based on this data, a greenhouse of this size would cost $191,000 and installation costs would be approximately $238,400, for a total of $429,439.

For comparison, following is an analysis of greenhouse construction costs (based on a 1996 publication) that assumes a greenhouse with a floor area of 21,120 ft^2. It also assumes that the least expensive construction approaches are used. Table 3-1 summarizes the construction estimates.

TABLE 3-1. GREENHOUSE CONSTRUCTION COSTS

ITEM	COST ($/ft^2)
Rigid Frame Wood Greenhouse	2.25
Site Prep/Driveway/Concrete Floor	4.05
Environmental Control (HVAC)	6.15
TOTAL (rounded)	12.45

The costs shown in this table were derived from Greenhouse Engineering, Aldrich, R.A. and Bartok, J.W., Northeast Regional Agricultural Service; Cornell University, Ithaca, NY, published in August 1996. The costs shown above were adjusted by an annual inflation rate of three percent over the costs provided by this source

The approximate total cost of greenhouse construction is calculated by multiplying the total square footage of floor area by the cost per square foot as shown below.

$$\left[21{,}120\,ft^2\right]\left[\frac{\$12.45}{ft^2}\right] = \$262{,}944$$

Thus, construction and installation costs are likely in the range of $263,000 to $430,000. Greenhouse construction firms can provide more accurate costs once more specific information is known about the types of crops to be grown and the proposed greenhouse's size, design, preferred building materials, and construction methods.

Heating System Cost Comparison

Though there can be yearly, monthly, or daily fluctuations, the U.S. Department of Energy (DOE) projects natural gas prices for commercial customers will be approximately $5.00 per million Btu (MMBtu) for the next few years. Therefore, in order for the project to be feasible from an energy purchasing standpoint, the cost to supply the greenhouse with LFG must be less than $5.00 per MMBtu.

The costs for installing and operating the LFG collection system, but not the cost to construct the greenhouse, are included in the economic evaluation. Therefore, the costs that are relevant from a fuel supply standpoint are those associated with collecting the LFG and the equipment necessary to convey the LFG from the blower/flare station to the greenhouse.

The installed capital cost of the LFG collection and delivery system is approximately $271,000. It is conventional to amortize these costs over the lifetime of the project rather than considering them as an expenditure made at a single point in time. The LFG generation models indicate that the site's gas recovery rates may be sufficient to supply the greenhouse's heating needs until approximately 2011-2015. Therefore, the capital cost of the collection and delivery system has been conservatively divided over a 10-year period, resulting in an annualized capital cost of $27,100 per year. The annual operating and maintenance costs of the collection and delivery system are $29,000 per year. Therefore, total annual costs to provide the greenhouse with LFG are $56,100 per year. (See Appendix C).

Based on the modeled gas recovery rate and preliminary greenhouse sizing information, the landfill can provide approximately 120 scfm of gas for use to heat the greenhouse. The cost of providing the LFG to the greenhouse is $1.78 per MMBtu, an approximation based on the following calculation:

$$\left[\frac{\$56{,}100}{\text{year}}\right]\left[\frac{\text{year}}{525{,}600\,\text{min}}\right]\left[\frac{\text{min}}{120\,\text{ft}^3\,\text{LFG}}\right]\left[\frac{\text{ft}^3\,\text{LFG}}{500\,\text{Btu}}\right]\left[\frac{10^6\,\text{Btu}}{\text{MMBtu}}\right]$$

$$= \$1.78 \text{ per MMBtu}$$

In other words, as long as the cost to purchase natural gas to heat the greenhouse is greater than $1.78 per MMBtu, it is economically feasible to use LFG for greenhouse heating.

This LFG cost per MMBtu was calculated assuming that 120 scfm of LFG is used year round in the greenhouse. In fact, given the location in Georgia, it is likely that the heat demand is seasonal. If you assume the greenhouse may only need to be heated for half the year, then the total amount of LFG used by the greenhouse each year might be only half as much as calculated.

This would cause the cost per MMBtu to increase, but the cost would still be less than double the $1.78 per MMBtu shown above. Even if the cost were up to $3.56 per MMBtu, the cost of using LFG to heat the greenhouse would still be less than the cost of using natural gas. As indicated previously, the LFG recovery potential at the site diminishes over time. One way to off-set this reduction in LFG could be to use a boiler with "dual-fuel" capability. That is, a boiler that is capable of using LFG, as well as, natural gas as a fuel source.

ELECTRICITY GENERATION

Two more options for using LFG are the use of either an internal combustion (IC) engine or a microturbine to generate electricity. If electricity is not required at the landfill, it can be distributed through the local power grid. This approach requires close cooperation with the electric power utility. Information is provided here about selling electricity to the grid system. It is important to note that the ultimate feasibility of this option depends on the electricity purchase rate paid by the local electric utility. Economies of scale tend to make this option more feasible as gas generation rates increase. Since this landfill produces a low gas flow, electrical sales to a utility company may not be a financially viable option. On-site use of electricity is potentially a more viable option. Although there are only a few on-site activities requiring electricity, they might provide a use for low-flow LFG. Also other uses of electricity can be developed on site, such as use in a greenhouse.

Microturbines

Microturbines are an emerging technology for generating electricity from LFG. The microturbine is a high-speed turbine-powered generator that produces stationary power. It has been used in aviation for some time but is now being demonstrated at several landfill sites. These units are compact power sources no larger than an industrial air conditioner. They are typically available in sizes ranging between 25 kW and 75 kW and can be chained together to produce more than 1 MW. NOx emissions from a microturbine have been demonstrated to be as low as 1.4 ppm. A single microturbine can function on as little as 14 scfm of LFG. Microturbines are very well suited for producing power for on-site use or for delivery to a power grid.

EMCON's pro forma model was used to estimate the relevant cost information because the E-Plus model does not account for microturbines (See Appendix C). For the purpose of this estimate, it was assumed that the facility would use six microturbines that would have a cumulative input capacity of approximately 126 scfm. Such a configuration would generate approximately 180 kilowatts (kW) of electricity. Based on the EMCON economic analysis, the installed cost of the microturbines is estimated to be approximately $590,000. This capital cost includes the purchase and installation of the microturbines, connection to the power grid, and the construction of a skid. The capital cost of the LFG collection system is $271,000, for a total estimated capital cost of $861,000. The estimated annual operation and maintenance cost for the microturbines was calculated to be approximately $18,000 per year, and the LFG collection system operation and maintenance costs are approximately $29,000 per year, for a total annual operating and maintenance cost of approximately $47,000 per year.

It is conventional to amortize these costs over the lifetime of the project rather than considering them as an expenditure made at a single point in time. The LFG generation models indicate that the site's gas recovery rates may be sufficient to supply the microturbine's fuel needs until approximately 2011-2015. Therefore, the capital cost for constructing the electricity generation power plant has been depreciated over 10 years.

Financial Results

The revenue potential from electricity generation was estimated. It was assumed that electricity could be sold for $0.05 per kWh. The financial analysis is summarized below:

• Capital Cost =	$861,000
• Annual Operations and Maintenance (O&M) Cost =	$47,000
• Loan Rate =	0 percent
• Loan Period =	10 years
• Discount Rate =	7 percent
• Inflation Rate for Costs =	4 Percent
• Net Present Value =	$(418,000)
• Internal Rate of Return =	Not Applicable
• Simple Payback =	16 Years

Based on an electricity sales price of $0.05 per kWh, this preliminary analysis indicates that this project is not economically feasible unless combined with other financial incentives. As shown in Appendix C, the electricity sales price that would be needed to achieve a 7 percent internal rate of return is $0.11 per kWh. Appendix C also provides a break-even analysis that indicates that the electricity created in the microturbines would have to be sold for $0.0952 per kWh to break even over a 10-year period with a zero internal rate of return.

On Site Use of Electricity

Also examined was whether the landfill could use microturbines to generate electricity for internal use. However, based on the landfill's electricity bills, its electricity use is quite low. The landfill could use only a small fraction of the electricity that could be generated by its LFG for internal use. Thus, in order to use all of the site's LFG, electricity would need to be sold. For this reason, the internal use option was not examined in detail. The option of direct use of LFG in a greenhouse appears to be much more feasible than generating electricity for internal use with microturbines.

Internal Combustion Engines

Internal combustion (IC) engines are the most commonly used conversion technology in LFG applications. They are stationary engines, similar to conventional automobile engines. They can use medium-Btu gas to generate electricity. While they can range from 30 to 2,000 kW, IC engines associated with landfills typically have capacities of 400 to 1,000 kW. IC engines are a proven and cost-effective technology that can use LFG as a fuel, provided that the LFG has a minimum energy content of 450 Btu/ft^3. Their flexibility, especially for small generating capacities, makes them a convenient option for smaller landfills.

Impurities in landfill gas can cause corrosion in IC engines. Impurities may include chlorinated hydrocarbons that can react chemically under the extreme heat and pressure of an IC engine. This problem is generally solved by pretreatment (primarily moisture removal) of LFG before it reaches the IC engine. Other impurities of concern include silicon-containing compounds (i.e., siloxanes), which oxidize during combustion and form a sand-like compound. This type of abrasive byproduct can cause significant damage to IC engines. Another consideration is that IC engines are relatively inflexible with regard to their air-fuel ratio, which may fluctuate along with the quality of the LFG. Some IC engines also produce significant nitrogen oxide (NOx) emissions, although designs exist which minimize this problem.

A small IC engine could be a viable option for this landfill. A single small IC engine requires about 134 scfm of landfill gas flow to operate. It is questionable whether there is enough gas flow from this landfill to operate this size IC engine at its full capacity for 10 years. However, the viability of an IC engine can be more accurately assessed after the landfill gas collection system is in place. As with the microturbine, electricity generated with an IC engine may either be sold to a local electric utility or used on-site.

The E-Plus model evaluated costs for a 417 kW IC engine and determined that the capital cost for this option is approximately $834,700, including the purchase and installation of the engine, connection to the power grid, gas treatment, the container to house the engine, and the gas collection system. (See Appendix D.) The E-Plus model also predicts that the annual operation and maintenance cost for this option is $120,400 per year.

It is conventional to amortize these costs over the lifetime of the project rather than considering them as an expenditure made at a single point in time. The LFG generation models indicate that the site's gas recovery rates may be sufficient to supply the microturbine's fuel needs until approximately 2011-2015. Therefore, the capital cost for constructing the electricity generation power plant has been depreciated over 10 years. Therefore, the capital cost for constructing the electricity generation power plant has been depreciated over 10 years.

Financial Results

The revenue potential from electricity generation and sales was estimated using an assumed sale price of $0.05 per kWh. The financial analysis provided by the E-Plus model is summarized below:

- Capital Cost = $834,700
- Annual Operations and Maintenance (O&M) Cost = $120,400
- Loan Rate = 0 percent
- Loan Period = 10 years
- Discount Rate = 7 percent
- Inflation Rate for Costs = 4 Percent
- Net Present Value = $(499,960)

- Internal Rate of Return = 0.0 percent
- Simple Payback = 18 years

Based on the electricity sales priced of $0.05 per kWh, this preliminary analysis indicates that this project is not economically feasible. It has a negative net present value and the simple payback (18 years) is longer than the expected period of the project based on the LFG generation rate. As shown in Appendix D, the electricity sales price that would be needed to exceed a 7 percent internal rate of return is $0.0710 per kWh.

For the purpose of comparison, we also used EMCON's pro forma model to estimate the expenses and income of operating an IC engine with LFG. The EMCON model produced results which were in general agreement with the results of the E-plus model. Based on a break-even analysis continued in EMCON's proforma model electricity generated from the IC Engine would have to be sold for $0.0533 per kWh to break-even with a zero internal rate of return.

On Site Use of Electricity

We considered whether the landfill could use an IC engine to generate electricity for internal use. However, based on the landfill's electricity bills, its electricity use is quite low. The landfill could use only a small fraction of the electricity that could be generated by its LFG for internal use. Thus, in order to use all of the site's LFG, electricity would need to be sold. For this reason, the internal use option was not examined in detail. The option of direct use of LFG in a greenhouse appears to be much more feasible than generating electricity for internal use with an IC engine.

CONCLUSIONS

Based on the background information provided to EMCON/ERG, it appears that a sufficient amount of LFG is generated at Rocky Face Landfill to allow LFG recovery for use on a small greenhouse project. Since a greenhouse located in Georgia is unlikely to require gas heating year-round, the operators of the Rocky Face Landfill may wish to explore additional ways in which LFG could be used in the warmer months. One particularly promising approach that has been implemented elsewhere is the installation of craft studios for glass-blowing and pottery. In the summer, when LFG is not useful for warming a greenhouse, it could be used as an energy source to power glass furnaces and/or pottery kilns. Two other applications of LFG that are currently being explored include powering a cold storage chiller for local produce and fueling a firefighter training facility.

Additional information about powering craft studios can be obtained by contacting Stan Steury at the Blue Ridge Resource Conservation and Development Council, Inc., an organization that has pioneered the use of LFG for this purpose. Contact information is as follows:

Blue Ridge Resource Conservation and Development Council, Inc.
Attn: Stan Steury
1081-2 Old U.S. 421
Sugar Grove, NC 28679

(828) 297-5805
(828) 297-5928 (fax)
blueridge@skybest.com

A project using an IC engine or microturbines to generate electricity for sale does not appear to be financially feasible from our analysis of the available information. The cost of generating the electricity exceeds the revenue that would be generated from sales. However, if a utility such as TVA is willing to pay a premium price for the landfill gas electricity to include it in a green energy portolio, the electricity generation options may become more feasible.

It is assumed that a LFGTE project at the Rocky Face Landfill will be eligible for a zero interest loan from the Georgia Environmental Facilities Authority (GEFA) Loan/Grant Program. The economic analyses in this document have included a zero interest loan. (More information about the GEFA Program can be found in Appendix E). Additional incentives can make the use of the LFG for a greenhouse even more desirable and may even make the use of an IC engine or microturbine feasible. For example:

- **Good Public Relations and Environmental Control** - Because they use an otherwise wasted resource and also help to prevent air pollution, LFG projects can provide significant positive public relations for the landfill owner. Even if the project is not economically attractive, non-monetary incentives may be enough reason to pursue LFG utilization.

- **Tax Credits or Grants** - If tax credits are available from the government, the economics for LFG recovery can improve substantially. An example of these are tax credits for generating power from “clean” or renewable fuels, or for installing environmental controls that are more stringent than those required by law. Currently, these types of incentives for LFG have been proposed by Congress and the administration and are pending approval. If such incentives become available in the future, they could greatly enhance the profitability of LFG project development.

- **Green Pricing Programs** – Currently, Georgia is developing a green pricing accreditation program which will allow electricity providers to offer green energy to consumers at a premium price. Current proposals would allow landfill gas-generated electricity to be included in green pricing programs if the electricity generation equipment meets specific NOx emission levels (still to be determined). If this program takes effect, it may increase the price at which Dalton-Whitfield could sell electricity and improve the feasibility of the IC engine or microturbine options. For more information and updates on the status of the green pricing accreditation program, contact Whitney Aquilera at 404-659-5675 or whitney@cleanenergy.ws. The TVA also has two programs (Green Power Block Program and Renewable Energy Portfolio) that purchase green power. Currently, only the Renewable Portfolio is effective for the purchase of green power from biomass. For more information on green power purchases by the TVA, please contact Tom Swanson, Senior Manager of the Power Resources Department, at (423) 751- 6741, tswanson@tva.gov or Gary Harris, Manager of the Green Power Switch Department, at (615) 232-6124, gharris@tva.gov

SECTION 4

ENVIRONMENTAL BENEFITS

In addition to being a potentially valuable resource for energy production, landfill gas is also considered an air pollutant. Landfill gas contains methane, a potent greenhouse gas. In terms of its heat retention capacity, methane is approximately 21 times more potent than carbon dioxide. In other words, one unit of methane can retain 21 times more heat than the same unit of carbon dioxide (CO_2). As our society continues to be concerned about the possibility that human activities and industry could accelerate global warming, attention has been focused on ways to reduce emissions of greenhouse gases. Utilizing LFG for energy is one way to mitigate those harmful effects.

LANDFILL GAS METHANE REDUCTIONS

Landfill gas recovery projects provide a decrease in overall greenhouse gas emissions from landfills because the methane is burned rather than being released. The end uses reviewed in this report (electricity generation, use as fuel to heat a greenhouse) would also destroy most of the non-methane organic compounds found in LFG.

The estimated amount of LFG combusted in the greenhouse and the microturbine applications is 120 and 108 scfm, respectively, at 50% methane. The IC engine evaluated using the E-Plus model has a slightly greater capacity, because the engine was sized to handle a higher flow (rather than the lowest possible flow) over the 10-year period. The model assumes a gas utilization of approximately 134 scfm. Based on these gas combustion rates, the following annual reductions would occur:

	Methane Reduction (Mg/yr)	Greenhouse Gas Reduction Equivalent ($MgCO_2$/yr)	Number of Cars Off the Road (Per Year)	Number of Acres of Trees Planted (Per Year)
Greenhouse	600	12,700	2,780	3,740
Microturbines	540	11,400	2,530	3,410
IC Engine	670	14,100	3,110	4,210

AVOIDED EMISSIONS

Additional benefits are obtained through the use of the methane in the LFG because it displaces the other fuels which would have otherwise generated that energy. The use of LFG to heat the greenhouse displaces natural gas. The use of LFG to generate electricity displaces other fossil fuel sources supplied to the Georgia energy grid. The avoided emissions, therefore, differ for these two cases.

Greenhouse Heating

The greenhouse gas emissions that are avoided for heating a greenhouse with LFG rather than natural gas are as follows:

- CO_2 Emissions Avoided = 1,640 Mg of CO_2 per year
- This is equivalent to taking 360 cars off the road or planting 490 acres of trees per year.

Electricity Generation

By using the otherwise wasted methane contained in the collected LFG to generate electricity, fuels such as oil and coal that typically provide fuel for electricity generation are displaced. To calculate avoided CO_2 and sulfur dioxide (SO_2) emissions, we used the EGRID2000 database to determine the amounts of CO_2 and SO_2 emissions per Megawatt hour from energy generation in the state of Georgia, which reflects the mix of fuels and power generation techniques for the Georgia energy grid. The emissions avoided by using LFG to generate electricity in each of the electricity generation options is presented below.

For the microturbines, which have a combined capacity of 180 kW:

- CO_2 Emissions Avoided = 882 Mg per year
- SO_2 Emissions Avoided = 7 Mg per year
- This is equivalent to taking 190 cars off the road or planting 260 acres of trees per year.
- The potential kilowatts that can be produced by these microturbines could power 120 U.S. homes.

For the IC engine, which has a capacity of 418 kW (evaluated using the E-plus model):

- CO_2 Emissions Avoided = 1,760 Mg per year
- SO_2 Emissions Avoided = 14 Mg per year
- This is equivalent to taking 388 cars off the road or planting 520 acres of trees per year.
- The potential kilowatts that can be produced by the IC engine could power 280 U.S. homes.

SECTION 5

NEXT STEPS TO PROJECT DEVELOPMENT

This section identifies some of the next steps for moving forward on project development. LMOP can provide assistance related to many of these steps as listed below.

IDENTIFY ENERGY END USER

An end-user of the gas or electricity must first be identified. Future Farm (a division of American Hydroculture, Inc.) is interested in using the site's LFG for a greenhouse, but they would like 2 MW of energy, which would require more gas than what the landfill can provide. It is possible that the landfill can provide enough gas to Future Farms that the project can still be pursued if Future Farms is willing to consider a smaller greenhouse or to use natural gas or purchase electricity for the portion of their energy needs the landfill could not provide. Also, it is possible that electricity from the landfill gas can be sold the to the Tennessee Valley Authority to be included in their renewable energy portfolio, or that the Georgia green pricing program currently under development could interest other Georgia electricity providers in purchasing electricity from the landfill gas.

ESTABLISH PROJECT STRUCTURE

This type of project can be structured in a variety of different ways. The most common is to solicit for a third party developer. The landfill would send out an RFP to solicit bids from third party developers. The landfill could accept the best bid received to develop the project. However, projects have been developed where the landfill owner has developed and managed the project internally. Under this plan, the landfill manager develops partnerships with equipment suppliers and the energy end user.

PERFORM MORE DETAILED FEASIBILITY EVALUATION

Because of the uncertainty in LFG flow rate, it would be prudent to install the gas collection system before entering into any agreements to sell gas. This will allow site personnel, through the use of specialized equipment (GEM 500, ADM 870, etc.), to accurately measure the amount of LFG available for use. Also, it will be important to look at project economics more carefully to include site-specific interest rates, prices, and any local or federal government incentives which may be available. The developer may perform such an evaluation.

DRAFT DEVELOPMENT CONTRACT

Once the project structure is determined, a draft development contract is recommended. This contract would determine gas rights, rights to any emission reduction benefits, and the responsibilities of different partners for the different components of the project (e.g., design, installation, environmental compliance, and operation and maintenance).

ASSESS FINANCING OPTIONS

There are a variety of options for financing projects, including the potential for grants. Some of the options include:

- Private equity financing
- Project financing
- Municipal bonds
- Direct municipal bonds
- Grants/Loans
- REPI – Renewable Energy Production Incentive

NEGOTIATE CONTRACT

The sale of LFG is not a typical business transaction for landfill owners. Therefore, the negotiation of the LFG sales contract is typically handled by a third party developer or an attorney that specializes in this work. Some of the steps that will take place include:

- Preparing a draft offer contract
- Determining the LFG needs
- Developing project design and pricing
- Preparing and presenting bid package
- Reviewing contract terms and conditions
- Signing contract

The final steps include securing permits and approvals, contracting for engineering, installing the project, and starting up operations.

Please see Appendix F for a more detailed outline of next steps.

APPENDIX A

LFG SAMPLING RESULTS

Dalton – Whitfield Regional Solid Waste Management Authority
Westside Landfill

Vent ID	Methane (%)	Carbon Dioxide (%)	Oxygen (%)	Balance Gas (%)	Pressure (" WC)
V-1	62.2	35.5	0.8	1.5	0
V-2	5.5	4.5	17.7	72.3	0
V-3	39.5	25.5	7.6	27.4	0.1
V-5A	60.5	35.1	0.8	3.6	0.1
V-6	61.8	36.2	0	2	0.5
V-7	59.2	34.6	0.9	5.3	0.5
V-8	58.7	33.6	0.9	6.8	0.5
V-9	59.1	35.6	0.5	4.8	0.6
V-10	55.3	36.2	1	7.5	0.4
V-11	37.3	29.6	0.7	32.4	0.3
V-12	48.8	32.8	2.1	16.3	0.4
V-13	51.1	35	1.5	12.4	0.2
V-14	59.6	38.3	0	2.1	0.5
V-15	45.8	30.9	4.3	19	0
V-16	57.9	33	1.4	7.7	0.4
V-17	56	33.7	1.6	9.7	0.3
V-18	63.3	36.7	0	0	0.3
V-19	57.9	34.8	1.6	5.7	0.1
V-20	62.1	36.2	0.3	1.4	0.6
V-21	64.4	35.5	0.1	0	0.3
V-22	64.2	35.8	0	0	0.4
V-23	62.2	36.4	0.6	0.8	1.3
V-24	62.5	37.5	0	0	2.4
V-25	61.1	37	0.4	1.5	0.5
V-26	62.1	35.9	0.7	1.3	0.5
V-27	62	38	0	0	0.4
V-28	58.4	39.4	0	2.2	0.4
V-29	48.2	31.5	1.9	18.4	0.1
V-30	47.2	34.3	0	18.5	0.2
V-31	49.7	34.6	0.8	14.9	0.4
V-32	36.8	26.8	3.5	32.9	0.1
V-33	54.8	37.6	0	7.6	0.4
V-34	57.4	38.2	0	4.4	0.4
V-35	55.3	36.5	0	8.2	0.3
V-36	56.7	38.6	0.2	4.5	0.6
V-37	55.6	33.9	1.8	8.7	0.4
V-38	30.8	20.4	9.5	39.3	0.8
V-39	60.2	37	0.3	2.5	0.5
V-40	63.1	36.9	0	0	1.9
V-41	58.1	37	1	3.9	5.8

Dalton – Whitfield Regional Solid Waste Management Authority
Westside Landfill
(Continued)

Vent ID	Methane (%)	Carbon Dioxide (%)	Oxygen (%)	Balance Gas (%)	Pressure (" WC)
V-42	62	38	0	0	0.3
V-43	53.4	31.9	3.2	11.5	0
V-44	57.7	37.3	0.9	4.1	0.1
V-45	61.8	38.2	0	0	0.2
V-47	39.1	25.6	3.7	31.6	0.1
V-48	11.7	16.3	4	68	0.1

Note: All vents were sealed for 30 minutes prior to sampling

APPENDIX B

EMCON GAS GENERATION MODEL OUTPUT

Please note that this model, like any other mathematical projection, should be used only as a tool, and not an absolute declaration of the rate of LFG generation. Fluctuations in the rate and types of incoming waste, site operating conditions, refuse moisture and temperature may provide substantial variations in the actual rates of LFG generation and recovery.

This model has been prepared under the current standards of engineering practice, and is based upon the information available at the time of development. No other guarantees, either implied or expressed, are warranted.

LANDFILL GAS GENERATION MODEL INPUT SUMMARY
Dalton-Whitfield

General Information

Analysis performed by:	Juene Franklin
Project number:	821290
Date of analysis:	05/10/01

Analysis Timeframe

Opening year of the landfill:	1972
Closing year of the landfill:	1999
Analysis performed through the year:	2011

Site Operating Conditions

Refuse moisture condition:	Moderately Wet
Refuse temperature:	100 °F
Average compacted refuse density:	1,200 lb/cy

LFG System Recovery Efficiency

ID Number	Recovery Efficiency	Effective Period
1	75%	1972 - 2011

Waste Stream Composition

Component	Composition 1	Composition 2
Organics		
Food waste	9.0%	N/A
Garden waste	19.0%	N/A
Paper waste	33.0%	N/A
Other organics	7.0%	N/A
Organic Subtotal	68.0%	N/A
Inorganics	32.0%	N/A
Total	100.0%	N/A

Generation Rate Properties

Rapid subgroup conversion time:	4 yrs
Intermediate subgroup conversion time:	30 yrs
Slow subgroup conversion time:	100 yrs

EPA Modeling Parameters

Methane generation potential (L_o):	3,531 ft^3/Mg
Methane generation rate (k):	0.04 yr^{-1}
NMOC concentration (C_{NMOC}):	595 ppmv

Summary of Results
Dalton-Whitfield
821290

Year	Annual Refuse Acceptance Rate (tons)	Cumulative Refuse Acceptance Rate (tons)	Upper limit of LFG Generation Rate (scfm)	Lower limit of LFG Generation Rate (scfm)	Upper limit of LFG Recovery Rate (scfm)	Lower limit of LFG Recovery Rate (scfm)	Average LFG Energy Rate (MMBtu/hr)
1972	30,000	30,000	0	0	0	0	0
1973	30,000	60,000	6	4	4	3	0
1974	30,000	90,000	13	9	10	7	0
1975	30,000	120,000	24	16	18	12	1
1976	30,000	150,000	40	27	30	20	1
1977	30,000	180,000	61	41	46	31	2
1978	30,000	210,000	86	57	64	43	2
1979	30,000	240,000	112	75	84	56	3
1980	30,000	270,000	136	91	102	68	4
1981	30,000	300,000	156	104	117	78	4
1982	30,000	330,000	175	117	131	87	5
1983	30,000	360,000	192	128	144	96	5
1984	30,000	390,000	208	138	156	104	5
1985	30,000	420,000	222	148	167	111	6
1986	30,000	450,000	235	157	177	118	6
1987	30,000	480,000	248	165	186	124	6
1988	30,000	510,000	259	173	194	129	7
1989	30,600	540,600	269	180	202	135	7
1990	27,640	568,240	279	186	209	140	7
1991	20,921	589,161	288	192	216	144	7
1992	24,520	613,681	294	196	220	147	8
1993	21,530	635,211	300	200	225	150	8
1994	23,789	659,000	303	202	228	152	8
1995	24,330	683,330	306	204	229	153	8
1996	24,188	707,518	306	204	230	153	8
1997	37,166	744,684	306	204	229	153	8
1998	26,675	771,359	308	205	231	154	8
1999	1,474	772,833	309	206	232	155	8
2000			307	205	230	153	8
2001			304	203	228	152	8
2002			299	199	224	150	8
2003			289	193	217	145	8
2004			274	183	205	137	7
2005			254	169	190	127	7
2006			232	154	174	116	6
2007			212	141	159	106	5
2008			195	130	146	97	5
2009			179	120	135	90	5
2010			165	110	124	83	4
2011			152	101	114	76	4

APPENDIX C

COST SUMMARY TABLE USING EMCON PRO FORMA

LMOP FEASIBILITY STUDY
ROCKY FACE LANDFILL - WESTSIDE PHASES 1 & 2
DALTON, GEORGIA

11/19/01

Capital Expenditures

K:\0144\002\005\[DaltonWhitfield_CapEx-5.xls]CapEx

			Microturbine	Greenhouse
Description - Electric Plants				
Number of Units Installed			6	
Capacity in kW	kW		180	
Fuel requirement @ 50% CH4	scfm		108	
Parasitic loads			28	
Avg. Utilization			88%	
Description - Greenhouse				
Size - Base Unit & Add On Unit				22 x 96
Area				2,112
No. of Base Units				1
No. of Add On Units				9
Heating requirements - low	Btu/hr.			200,000
Heating requirements - high	Btu/hr.			350,000
Fuel requirement @ 50% CH4 - low	scfm			7
Fuel requirement @ 50% CH4 - high	scfm			12
Capital Costs				
Equipment Quote			332,982	191,067
Shipping, duties, insurance etc.			10,000	
Unloading			2,000	
Subtotal			344,982	191,067
Installation				
Mob/demob			$ 3,857	
Concrete			9,514	
Gravel				
Fencing				
Labor			67,886	
Materials			Incl. In labor	
Crane Rental				
Project Mgr.				
Electrical Allowance			125,400	
Mfg. Installation Allowance				207,280
Contingency		15%	30,999	31,092
Subtotal			237,656	238,372
Financing Costs (Loan of $500,000, 0% interest)			7,500	7,500
			1.5%	1.5%
Total Installed Cost			$ 590,138	$ 436,939
Cost per kW of capacity			$3,279	
Cost per SF of Greenhouse Space				$ 20.69
Operating Costs (Net kWh)				
O&M	per kWh		0.01293	
Major Overhaul	per kWh			
Contingency		16%	0.00207	
			$ 0.01500	$ -
Annual Cost			$ 17,552	$ -

LMOP FEASIBILITY STUDY
ROCKY FACE LANDFILL - WESTSIDE PHASES 1 & 2
DALTON, GEORGIA

11/19/01

Capital Expenditures

K:\0144\002\005\[DaltonWhitfield_CapEx-5.xls]CapEx

			Microturbine	Greenhouse
All-In Cost including Gas Collection Control System				
Installed Cost of Facility			$ 590,138	$ 436,939
Installed cost of GCCS			271,050	271,050
			$ 861,188	$ 707,989
Amortization of Capital				
	term in years	10	86,119	70,799
	rate	0%		
Annual Gas collection System O&M Cost			29,000	29,000
Annual Facility O&M Cost			17,552	-
Total Annual Cost			132,670	99,799
kWh production - annually			1,170,196	
Cost per kWh - approx.			$ 0.113	

Gas Collection Control System Cost				
Gas Collection System per E-Plus			294,770	
Less: Well drilling (wells in place)			(48,720)	
				246,050
Add: 1000 feet of 6" HDPE pipe to Facility				22,000
				3,000
Total Capital Cost				271,050
Amortization of Capital Cost				
	term in years	10		27,105
	rate	0%		
Annual Gas collection System O&M Cost				29,000
				$ 56,105

$$\left[\frac{\$56{,}105}{year}\right]\left[\frac{year}{525{,}600\,\min}\right]\left[\frac{\min}{120\,ft^3 LFG}\right]\left[\frac{ft^3 LFG}{500\,Btu}\right]\left[\frac{10^6\,Btu}{MMBtu}\right]$$

per MMBtu **$ 1.779**

LMOP FEASIBILITY STUDY
ROCKY FACE LANDFILL - WESTSIDE PHASES 1 & 2
DALTON, GEORGIA

11/19/01

Financial Summary

	Results at Sale Price of $0.05 per kWh	KWH Selling Price required to Yield 7 % IRR
	MICROTURBINES	MICROTURBINES
Electricity Generation	6 MICROTURBINES	6 MICROTURBINES
Electricity Sale Price / kWh	**$ 0.050**	**$ 0.109**
Landfill Gas Purchase Price per MMBtu	$ -	$ -
Production Capacity in kW	180	210
Project Life	10 Years	10 Years
Capital Cost - including GCCS	$ 861,000	$ 861,000
Annual Operations & Maintenance Cost	$ 47,000	$ 47,000
Loan Amount	$ 500,000	$ 500,000
Loan Rate	0.0%	0.0%
Loan Period	10 Years	10 Years
Discount Rate	7.0%	7.0%
Inflation rate for Costs	4.0%	4.0%
Net Present Value	$ (418,000)	$ -
Internal Rate of Return	N/A	7.0%
Simple Payback	16.0	7.0

Gas Supply to Greenhouse

Cost of GCCS and Pipelines to Greenhouse	$ 271,000	Greenhouses owned by others. Dalton-Whitfield to own GCCS and pipeline to greenhouses.
Amortization of capital @ 0%, 10 years.	$ 27,100	
Annual Gas Collection System O&M Cost	29,000	
Total Annual Cost	$ 56,100	
Cost of LFG to Greenhouse	**$ 1.78**	

Cost of LFG Calculation

$$\left[\frac{\$56{,}100}{year}\right]\left[\frac{year}{525{,}600\min}\right]\left[\frac{\min}{120 ft^3 LFG}\right]\left[\frac{ft^3 LFG}{500 Btu}\right]\left[\frac{10^6 Btu}{MMBtu}\right]$$

IT GROUP

EMCON/OWT SOLID WASTE SERVICES – BREAK-EVEN ANALYSIS

24-Oct-2001

ASSUMPTIONS

Dalton-Whitfield installs and operates an electricity generating plant.

Gensets installed – MicroTurbines – number of units = 6

Power sale price per kWh = $0.0952

Total project installed cost = $861,188 Includes GCCS

		POWER RATE – Fixed Contract		
PROJECT NAME:	DALTON-WHITFIELD LF	POWER RATE – Other	$0.0952	Per kWh
PROJECT DESCRIPTION:	MICROTURBINES	POWER RATE INFLATOR	0.00%	Per YR.
PROJECT CAPACITY:	180 kW	GAS COST	$0.0000	PER K
CAPITAL COST	$5,741,251 per mW	GAS COST INFLATOR	0.00%	Per YR.
FINANCING - loan to cost	58.57%	O&M COST	$0.0150	Per KWh (net)
FINANCING - interest rate	0.00%	O&M COST INFLATOR	4.00%	Per YR.
GASCO OWNERSHIP	100.00%	ENERGY GRANT per kWh	$0.0000	

N:\PROJ\GASRECOV\LMOP\RockyFlats\RockyFace_MicroTurbine_1AAA.qpw

FINANCIAL PERFORMANCE SUMMARY

	YEAR1		10 YEAR		15 YEAR	
	$	CENTS/KWH	$	CENTS/KWH	$	CENTS/KWH
OPERATING STATISTICS						
KILOWATT HOURS SOLD	1,156,320		11,153,118		14,789,608	
CAPACITY FACTOR	88.00%		88.00%		88.00%	
INCOME STATEMENT						
TOTAL REVENUES	$110,082	9.52	$1,061,177	9.52	$1,407.971	9.52
COSTS OF REVENUES	17,345	1.50	167,297	1.50	221,844	1.50
GROSS PROFIT	92,737	8.02	894,480	8.02	1,186,127	8.02
DEPRECIATION and AMORTIZATION	86,119	7.45	861,188	7.72	861,188	5.82
ADMINISTRATIVE EXPENSE	3,302	0.29	31,853	0.29	42,239	0.29
INCOME BEFORE DEBT SERVICE	3,316	0.29	1,439	0.01	282,7000	1.91
INTEREST COST	0	0.00	(0)	-0.00	(0)	-0.00
INCOME BEFORE INCOME TAXES	3,316	0.29	1,439	0.01	282,700	1.91
INCOME TAXES	0	0.00	0	0.00	0	0.00
TAX CREDITS	0	0.00	0	0.00	0	0.00
NET INCOME	$3,316	0.29	$1,439	0.01	$282,700	1.91
CASH FLOW						
OPERATIONS						
NET INCOME	$3,316	0.29	$1,439	0.01	$282,700	1.91
ADD BACK:						
DEPRECITION and AMORTIZATION	86,119	7.45	861,188	7.72	861,188	5.82
INTERESTS COSTS	0	0.00	(0)	-0.00	(0)	-0.00
CASH FLOW AVAILABLE FOR DEBT SERVICE	89,434	7.73	862,627	7.73	1,143,887	7.73
DEBT SERVICE						
PRINCIPAL PAYMENTS	(50,000)	-4.32	(500,000)	-4.48	(500,000)	-3.38
INTERESTS COSTS	0	0.00	0	0.00	0	0.00
TOTAL DEBT SERVICE	(50,000)	-4.32	(500,000)	-4.48	(500,000)	-3.38
CASH FLOW AFTER DEBT SERVICE	39,434	3.41	362,627	3.25	643,887	4.35
INVESTMENT						
CAPITAL EXPENDITURES	(861,188)	-74.48	(861,188)	-7.72	(861,188)	-5.82
PROCEEDS OF FINANCING	500,000	43.24	500,000	4.48	500,000	3.38
NET INVESTMENT REQUIREMENTS	(361,188)	-31.24	(361,188)	-3.24	(361,188)	-2.44
CASH AVAILABLE (REQUIRED)	($321,753)	-27.83	$1,439	0.01	$282,700	1.91

	RATE	YEAR1	10 YEAR	15 YEAR
INTERNAL RATE OF RETURN			**0.1%**	**7.7%**
SIMPLE PAYBACK in YEARS		**10**		
DEBT COVERAGE RATIO			**1.73**	
NPV of AFTER TAX CASH FLOWS				
	3.00%	**($313,497)**	**($47,392)**	**$(139,657)**
	7.00%	**($303,115)**	**($94,391)**	**$16,453**
	10.00%	**($295,762)**	**($119,841)**	**($43,887)**
EBIT		**$3,316**	**$1,439**	**$282,700**
EBITDA		**$89,434**	**$862,627**	**$1,143,887**

APPENDIX D

E-PLUS MODEL OUTPUT

E-Plus Analysis

Summary Report

Landfill: Rocky Face Landfill

Design Scenario: IC Engines for Electricity Generation

Author: Juene Franklin, EMCON

Date: November 2001

This assessment was performed using E-PLUS, Version 2.0 Beta. Analyses performed using E-PLUS are considered preliminary and are to be used for guidance only. It is imperative that a detailed final feasibility assessment be conducted by qualified landfill gas recovery and utilization professionals prior to preparing a design, initiating construction, purchasing materials, or entering into agreements to provide or purchase energy from a landfill gas project.

Summary Results

Based on the project definition, landfill characteristics, and financial assumptions provided, the following summary results are estimated:

Project Start Year: 2002

Project Lifetime: 10

Electricity Capacity: 418 kW for electricity sales

Average Electricity Price: $0.0568 per kWh, averaged over the life of the project

Gas Sales Capacity: 0 MMBTU/year for gas sales

Average Gas Price: $0.00 per MMBTU, averaged over the life of the project

Financial Results:

Net Present Value:	$- 499,960
IRR:	0
Simple Payback:	18.2 years
Capital Costs:	$ 834,676
O&M Costs:	$ 120,428 per year, averaged over the life of the project

These financial results include the costs associated with the gas collection and flaring system. As defined, the landfill does not trigger the recently promulgated NSPS/EG emissions control requirements using the Tier 1 calculation method.

Landfill Characteristics

Open Year: 1972

Close Year: 1999

Current Year: 2001

Waste in Place: 772,833 tons, in 2001

Waste Acceptance Rate: 29,069 tons per year, from current year onward

Depth: 28 feet, maximum during landfill lifetime

Area: 29 acres, maximum during landfill lifetime

Gas Generation and Collection

Gas Generation from 1972 to 2032:

Annual Average:	42 mmcf/year of methane
	85 mmcf/year of landfill gas
Maximum:	74 mmcf/year of methane
	148 mmcf/year of landfill gas

Gas Generation During the Project: 2002 to 2012:

Annual Average:	47 mmcf/year of methane
	94 mmcf/year of landfill gas
Maximum:	63 mmcf/year of methane
	126 mmcf/year of landfill gas

Gas Collection Efficiency: 75 percent

Financial Assumptions

Project Start Year:	2002
Project End Year:	2012
Base Year for NPV Estimate:	2001

Downpayment Percent:	20 percent of total capital costs (remainder is borrowed)
Loan Rate:	0 percent
Loan Period:	10 years
Project Discount Rate:	7 percent
Marginal Tax Rate:	0 percent
Depreciation Method:	Straight Line
Inflation Rate for Costs:	4.0 percent per year
Collect and Flare Costs:	The costs associated with the gas collection and flaring system are included from the financial analysis.

Project Configuration Summary

Collection:	Included
Flare:	Included
Gas Treatment:	Included
Compression:	Included
Gas Enrichment:	Not Included
Electricity Production:	
Generation:	Included
Intertie:	Included
Sales	Included
Gas Production:	
Pipeline:	Not Included
Sales:	Not Included

Electricity Production and Sales Summary

Total Capacity:	418 kW
Average Generation:	2,769,105 kWh/year over the life of the project
Engine Load Factor:	75.67 percent over the life of the project
Average Electricity Price:	$0.0568 per kWh, averaged over the life of the project

Gas Production and Sales Summary

Gas Sales Capacity:	0 MMBTU/year for gas sales
Average Gas Price:	$0.00 per MMBTU, averaged over the life of the project
Average Production:	0 MMBTU/year over the life of the project

Price Analysis

Electricity Price: To achieve an IRR equal to the project evaluation discount rate of 7 percent, an average electricity price of $0.0710 per kWh is needed, average over the life of the project (assuming that the price for gas sales, if any, remains as defined in the project specification).

Gas Price: To achieve an IRR equal to the project evaluation discount rate of 7 percent, an average gas price of

$30.00 per MMBTU is needed, average over the life of the project (assuming that the price for electricity sales, if any, remains as defined in the project specification).

APPENDIX E

GEORGIA: RECYCLING AND SOLID WASTE LOAN PROGRAM

Background

The Georgia Environmental Facilities Authority (GEFA) provides environmental and energy efficiency financing, coordination, and education to governmental units and nonprofit organizations in Georgia. GEFA makes state-backed loans and grants to cities, counties, and solid waste management authorities for water, sewer, and solid waste management projects. GEFA is the primary funding agency for solid waste management projects in the state.

Program Description

Under the Recycling and Solid Waste Loan Program, GEFA offers low-interest loans for solid waste management projects, particularly those that help minimize waste streams or mitigate environmental hazards. Loan applications are accepted year-round. While GEFA loans are available only to Georgia local governments, partnerships with private-sector developers or project officers may be allowed, depending on the specific project arrangements. For example, if a private developer is developing a landfill gas utilization project for a publicly owned landfill, they can apply for the incentives.

GEFA offers both zero-interest loans and grants. The maximum loan amount is $3 million, with terms up to 20 years. GEFA provides grants for up to $50,000. Grant applications are accepted on an annual basis from early January through early April, and awards are made for one state fiscal year. (Grantees may apply for up to two 60-day extensions.) Grants are to be used to promote recycling, volume source reduction, composting and market development for recyclable materials. However, GEFA gives priority to innovative projects, such as landfill gas utilization projects, that bring together new resources and approaches to recycling, waste management, and waste reduction. Priority is also given to projects proposed by multi-jurisdictional or regional coalitions. Since 1984, GEFA has loaned $991 million to fund 818 city and county projects.

Actions you can take

If you are interested in developing a landfill gas utilization project: Review the program information on the GEFA web site. Contact GEFA to discuss the specifics of your project. If you are a city or county employee, review the Guidelines and Special Requirements of the Grants program.

If you are a state agency employee: Visit the GEFA web site to learn more about Georgia's program and consider whether it can serve as a model for your state.

For more information

Contact:
James Thompson
Georgia Environmental Facilities Authority
Suite 2090 Equitable Building

100 Peachtree Street NW
Atlanta, GA 30303-1911
404-656-0938
E-mail: thompson@gefa.org

Web site: www.gefa.org/gefa/recycling.html

APPENDIX F

STEPS TO LANDFILL GAS-TO-ENERGY PROJECT DEVELOPMENT

FOLLOW THE STEPS TO LANDFILL GAS-TO-ENERGY PROJECT DEVELOPMENT

Let the LMOP work with you through each step of...Landfill Gas-to-Energy Project Development

- Determine who your LMOP representative is
- Join LMOP's outreach or partner program
- Work with LMOP representative at each phase of project development

1. Estimate LFG Recovery Potential and Perform Initial Assessment or Feasibility Study

Desired Landfill Characteristics:

- Landfill is a MSW landfill
- Landfill has at least 1 million tons of MSW in place
- Landfill is at least 30 feet deep
- Site receives greater than 25 inches of rainfall annually
- Landfill has an existing gas collection system

Helpful LMOP Tools:

- LandGEM or EPLUS software
- Project Development Handbook

2. Evaluate Project Economics

Identify Energy End Users/Sales:

- On-site use (gas and electric)
- Nearby direct gas use
- Electricity use
- High-Btu upgrade (sales to nearby customers or gas utility)
- Specialty use (greenhouse, vehicle fuel, kilns)

Helpful LMOP Tools:

- Project Development Handbook
- EPLUS software

3. Establish Project Structure

Identify Who Will Develop/Manage the Project:

- Option 1: Develop/manage the project internally
- Option 2: Team with a project developer
- Option 3: Team with a partner (equipment supplier, energy end user, community)

Finding a Development Partner:

- Issue a Request for Proposals
- Acquire expressions of interests
- Solicit developers
- Negotiate with vendors

Helpful LMOP Tool:

- Industry ally list for reference, advice and distribution of RFPs

4. Draft Development Contract

- Determine gas rights
- Determine rights for potential emission reductions
- Determine partner responsibilities, i.e.:
  - design
  - installation
  - operation and maintenance

Helpful LMOP Tool:

- Project Development Handbook

5. Determine Financing Options

- Private equity financing
- Project financing
- Municipal bonds
- Direct municipal funds
- Grants
- REPI – Renewable Energy Production Incentive

Helpful LMOP Tools:

- Federal, foundation, and state grant guide
- State primers

6. Negotiate Energy Sales Contract

- Prepare draft offer contract
- Determine utility need for power
- Develop project design and pricing
- Prepare and present bid package
- Review contract terms and conditions
- Sign contract

7. Secure Permits and Approvals

Regulations:

Solid waste permit

- Air permit
- Local permitting issues
- Right-of-ways and easements

Procedures:

- Contact and meet regulatory authorities to determine requirements
- Educate about benefits of project and seek approval from landfill neighbors, local officials, and local environmental and public interest groups
- Assemble information, perform calculations and designs
- Submit complete permit applications to regulatory agencies
- Amend permit application (as needed)

Helpful LMOP Tools:

- NSPS Permit Guide
- State primers
- Community Outreach Primer

8. Contract for Engineering, Procurement & Construction, and Operation & Maintenance Services

- Owner/developer solicits bids from EPC/O&M contractors
- Owner/developer selects EPC/O&M contractor
- Owner/developer negotiates contracts
- EPC/O&M contractor conducts engineering design, site preparation, plant construction
- EPC contractor/developer conducts start-up testing

9. Install Project and Start Up Commercial Operation

- Ribbon cutting
- Public tours
- Press releases

Helpful LMOP Tools:

- Marketing and Promotion Primer
- Community Outreach Brochure

Potential Benefits Gained By Landfill Owners/Operators From LFGTE

Economic

Revenue shares from the sale of landfill gas or electricity produced

- Typical revenue for electricity = $0.03/kWh to $0.05/kWh
- Typical revenue for gas = $2.00/mmBtu to $4.00/mmBtu
- REPI[1] payments (municipal owners only) = 1.5 cents per kWh
- Royalty payments for gas extraction (private developer only) = varies

Offset the cost of a LFG collection/ control system

- Typical capital costs (1 million ton landfill) = $600,000 - $750,000
- Typical O&M costs (1 million ton landfill) = $40,000 - $50,000/yr

Market potential

- LFG = $2.00/ MMBtu (avg.) vs. natural gas = $3.00/ MMBtu vs. propane = $8.00/ MMBtu (avg.)

Other Areas of Revenue

- Emissions reductions
- Green power/green marketing program

Environmental

- Improve local air quality
- Lower risk of global climate change
- Reduce emissions from fossil fuels
- Subsurface migration control

Community Image

- Progressive, innovative resource usage
- Responsible community planning
- Safer landfill with reduced odors
- Job creation through project development
- Improved economic development near the landfill

Energy

- Reliable, local fuel source
- Less need for use of polluting fossil fuels

One Million Tons of Waste Yields Considerable Benefits

- 1 million tons of waste in place would typically generate 300 cubic feet per minute (cfm) of landfill gas, which could then generate 7,000,000 kilowatt hours (kWh) per year.
- 7,000,000 kilowatt hours (kWh) is enough energy to power 700 homes for a year.
- In terms of reducing greenhouse gas emissions, utilizing 300 cfm/year of landfill gas yields the same environmental benefit as removing 6,100 cars from the road for one year.
- Similarly, utilizing 300 cfm/year has the same environmental impact as planting 8,300 acres of trees.